Lakshminarayanan Krishnan
15CH21

Tutorial-1, 09/01/2017

National Institute of Technology, Surathkal
Department of Chemical Engineering
Heat Transfer-CH 251

State the assumptions clearly, with neat sketches solve the problems

1. A cylindrical resistor on a circuit board dissipates 0.8 W of power. Determine the amount of heat dissipated in 24 h, the surface heat flux, and the surface temperature of the resistor. Take the temperature of air around to be 40 °C and heat transfer coefficient as 9 W/m²°C. • 4cm diameter of cylindrical resistor.

Note: If Length isn't given; assume unit length ∴ L = 1m.

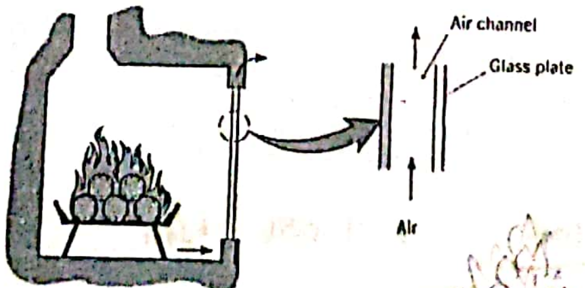
$P = \frac{Q}{t}$. $Q \Rightarrow 69120 J$. $d = 0.004m$

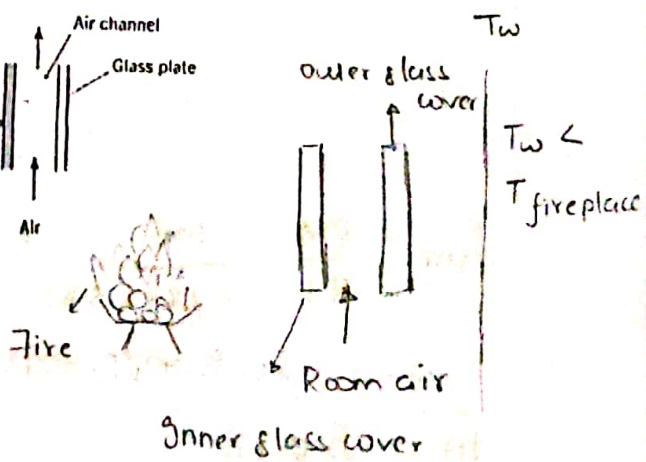
$\therefore A = \frac{\pi d^2}{2} + \pi d L = 0.01259 m^2$

$\therefore q = 63.53 Wm^{-2}$

$\therefore q = h(T_s - T_a) \Rightarrow T_s = 47°C$.

2. A double-glazed, glass fire screen is inserted between a wood burning fireplace and the interior of a room. The screen consists of two vertical glass plates that are separated by a space through which room air may flow(the space is open at the top and bottom). Identify the heat transfer processes associated with the fire screen.





q_1 : Net radiation heat exchange b/w fire and wall
q_2 : free convection from the hot air in the fire place to the innerwall
q_3 : conduction through inner glass
q_4 : free convection from outer surface of inner glass to room air
q_5 : free convection from room air to inner surface of outer glass
q_6 : outer glass conduction
q_7 : free convection from outer surface of outer glass to wall

3. It is necessary to insulate a kitchen oven with cork board (k=0.043 W/m K) so that the heat losses from the oven surface does not exceed 400 W/m2 when the inner surface of the oven is at 225°C and the outer surface of the oven is at 40°C. Determine the thickness of insulation required.

$k = 0.043 W/mk$. $T_1 = 225°C$; $T_2 = 40°C$, $q = 400 W/m^2$

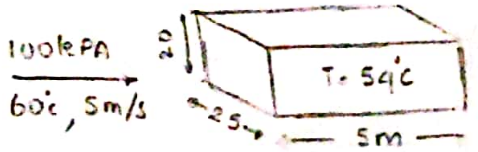
∴ We have $q = -k \frac{dT}{dx}$

∴ $dx = \frac{-k\,dT}{q}$

$= 1.988 \times 10^{-2} m$ is the thickness required

Note: Assuming steady state conduction within wall

4. A 5-m-long section of an air heating system of a house passes through an unheated space in the basement. The cross section of the rectangular duct of the heating system is 20cm x 25 cm. Hot air enters the duct at 100 kPa and 60°C at an average velocity of 5 m/s. The temperature of the air in the duct drops to 54°C as a result of heat loss to the cool space in the basement. Determine the rate of heat loss from the air in the duct to the basement under steady conditions. Also, determine the cost of this heat loss per hour if the house is heated by a natural gas furnace that has an efficiency of 80%, and the cost of the natural gas in that area is $1.60/therm (1therm = 105,500 kJ). Specific heat of air at 57°c; $C_p = 1.007 kJ/kg \cdot K$



$\rho_{air} = \frac{PM}{RT} = \frac{100}{0.287 \times 330} = 1.056 kg/m^3$

R when units are $\frac{kPa\,m^3}{kg \cdot k}$

$\dot{m} = \rho \times v \times A$

$= 1.056 \times 5 \times .2 \times .25 = 0.264 kg/s$

$\dot{Q}_{Loss} = \dot{m} C_p \Delta T = 0.264 \times 1.007 \times (6) = 1.595 kJ/s$

$Q_{Loss\ for\ 1\ hour} = 5742\ kJ/hr$

$x \times \frac{80}{100} = 5742$, $x = \frac{7177.5\ kJ/hr \times 1.60}{105,500} = .1086\ \$$

5. Two perfectly black surfaces are separated from each other and are enclosed such that all the radiant energy leaving the surface at 1000°C reaches the other surface maintained at 200°C. Calculate the net rate of radiation heat transfer per unit area of the first surface.
Ans. 146.46 kW/m²

$$\frac{Q}{A} = \sigma T^4$$

net rate of radiation heat transfer per unit area $= \sigma (T_1^4 - T_2^4)$

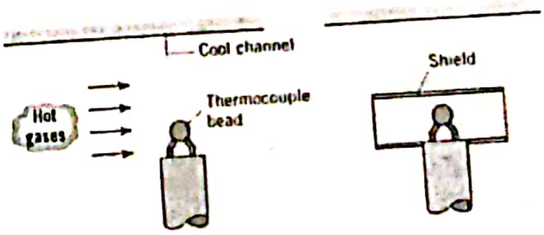
$$= 5.67 \times 10^{-8} (1273^4 - 473^4)$$

$$= 146 \text{ kW/m}^2$$

6. A small, thin metal plate of area A m² is kept insulated on one side and exposed to the sun on the other side. The plate absorbs solar energy at a rate of 500 W/m² and dissipates it by convection into the ambient air at T_a= 300K with a convection heat transfer coefficient h= 20W/m² °C and by radiation into a surrounding area which may be assumed to be a blackbody at T_{sky}=280 K. The emissivity of the surface is 0.9. Determine the equilibrium temperature of the plate.

7. Open the freezer door of your refrigerator. Put your face near it, but stay far enough away to avoid the downwash of cooled air. This way you cannot be cooled by convection, because the air between you and the freezer is a fine insulator, you cannot be cooled by conduction. Still your facecools perceptible. Why?

8. A themocouple junction(bead) is used to measure the temperature of a hot gas stream flowing through a channel by inserting the junction into the main stream of the gas. The surface of the channel is cooled such that its temperature is well below that of the gas. Identify the heat transfer processes associted with the junction surface. Will the junction sense a temperature that is less than, equal to, or greater than the gas temperature? A radiation shield is a small, open-ended tube that encloses the thermocouple junction, yet allows for passage of the gas through the tube. How does use of such a shield improve the accuracy of the temperature measurement?



National Institute of Technology, Surathkal
Department of Chemical Engineering
Heat Transfer-CH251
Tutorial-2

With neat sketches and justifiable assumptions, solve the problems

1. A large concrete slab 1 m thick has one dimensional temperature distribution:
   $T=4-10x+20x^2+10x^3$
   Where, T is temperature and x is the distance from one face towards other face of wall. If the slab material has thermal diffusivity of 2×10^{-3} m^2/h, what is the rate of change of temperature at the other face of the wall?
   (b) Why are metals good conductors of heat? motion of free electrons present
   (c) A composite wall of a furnace has 2 layers of equal thickness having thermal conductivities in the ratio of 3:2. What is the ratio of the temperature drop across the two layers?

$\alpha = 5.56\times10^{-7} m^2/h$

Sol. $T = 4-10x+20x^2+10x^3$

$\left.\frac{dT}{dx}\right|_{x=1} = -10+40x+30x^2 \cancel{= 80}°C$

$\left.\frac{d^2T}{dx^2}\right|_{x=1} = 40+60x = 100$

$\frac{d^2T}{dx^2} = \frac{1}{\alpha}\frac{dT}{dt}$

$\alpha(100) = \frac{dT}{dt}$

$\frac{dT}{dt} = 5.56\times10^{-5} \times 3600 = 0.2°C/h$

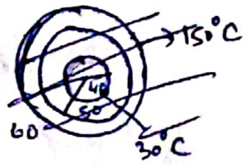
$\frac{k_1}{k_2} = 3/2$

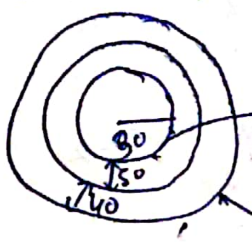
$\frac{x_1}{x_2} = 1$

$\frac{q_1}{q_2} = \frac{k_1\,\Delta T_1}{k_2\,\Delta T_2} = 2/3$

2. A tube 60 mm OD is insulated with a 50 mm layer of silica foam, for which the conductivity is 0.055 W/m °C followed with a 40 mm layer of cork with a conductivity of 0.05 W/m °C. If the temperature of the outer surface of the pipe is 150° C and the temperature of the outer surface of the cork is 30°C, calculate the heat loss in watts per metere of pipe.

$k_1 = 0.055\, W/m°C$
$k_2 = 0.05\, W/m°C$





$$\frac{Q}{L} = \frac{2\pi(150-30)}{\frac{\ln\left(\frac{80}{30}\right)}{0.055} + \frac{\ln\left(\frac{120}{80}\right)}{0.05}}$$

29.1 W/m

$$\frac{Q}{L} = \frac{2\pi\times120}{\frac{0.6}{0.055} + \frac{0.31}{0.05}} = \frac{240\pi}{10.9+6.2} = 44.09\, W/m$$

3. A hollow spherical vessel of inner diameter=19 cm and outer diameter=20 cm contains a hot fluid. The fluid is to be cooled by exposing the vessel to a surrounding cold fluid when the outside film coefficient is 10 W/m² K. If the vessel is to be lagged by mica sheet (k=0.5815 W/m K), determine the thickness of insulation so that the rate of heat transfer from the hot fluid is maximum.

→ $\cancel{\dfrac{2\times 0.5815}{10}}$

$r_{cr} = \dfrac{2\times 0.5815}{10}$

$= 0.1163\,m$

thickness $= (0.1163 - 0.1)\,m$

$= 0.0163\,m$

$= 1.68\,cm$

4. A infinitely long solid slab of thickness '2b' exposed to uniform flow of air over both its surfaces, at x=+b and x= -b. Assuming a steady state, heat flow to be in 'x' direction only, arrive at expressions for (a) temperature profile, (b) maximum temperature within the slab.

Assumptions
① one dimensional
② steady state

$x=-b \qquad x=0 \qquad x=+b$

$k\dfrac{d^2T}{dx^2} = -\dot{Q}_{gen}$

$\dfrac{d^2T}{dx^2} = -\dfrac{\dot{Q}_{gen}}{k}$

$\dfrac{dT}{dx} = -\dfrac{\dot{Q}_{gen}x}{k} + C_1$

$T = -\dfrac{\dot{Q}_{gen}x^2}{2k} + C_2$

$T_{fw} + \dfrac{\dot{Q}_{gen}b^2}{2k} = C_2$

$\cancel{T = T_{fw} + \dfrac{\dot{Q}_{gen}}{2k}(b^2 - x^2)}$

$\cancel{T = T_f + \dfrac{\dot{Q}_{gen}}{hL} + \dfrac{\dot{Q}_{gen}}{2k}(b^2-x^2)}$

$\left[\begin{array}{l} x=0 \quad dT/dx = 0 \\ \cancel{x=+b \quad T = T_{fw}} \\ x=\pm b,\ q = h(T_w - T_f) \end{array}\right]$

$(C_1 = 0)$

$\cancel{T_w @ T_f}$

$\cancel{\dfrac{\dot{Q}_{gen}A}{L} = hA(T_w - T_f)}$

$\cancel{\dfrac{\dot{Q}_{gen}}{Lh}} = T_w - T_f$

$T = T_f + \dfrac{\dot{Q}_{gen}b}{h} + \dfrac{\dot{Q}_{gen}b^2}{2k}\left(1 - \left(\dfrac{x}{b}\right)^2\right)$

5. A long copper bar of rectangular cross-section, whose width 'W' is much greater than its thickness 'L', is maintained in contact with a heat sink at its lower surface, and the temperature throughout the bar is approximately equal to that of the sink, To. Suddenly, an electric current is passed through the bar and an air stream of temperature T_∞ is passed over the top surface, while the bottom surface continues to be maintained at To. Obtain the differential equation and the boundary and initial conditions that could be solved to determine the temperature as a function of position and time in the bar.

$W >> L$

6. A plane wall 10 cm thick generates heat at the rate of 4×10^4 W/m³, when an electric current is passed through it. The convective heat transfer coefficient between each face of the wall and the ambient air is 50 W/m² K. Determine (a) Surface temperature, (b) Max temperature in the wall (c) Heat flow rate at the surface
Take $T_{ambient}$ = 20°C, and thermal conductivity of wall to be 15 W/m K

$T_f = 20°C$ $\quad h = 50 W/m^2K$ $\quad \dot{Q}_{gen} = 4 \times 10^4$

$k = 15 W/mK$

at $x = b$ $T = T_s$

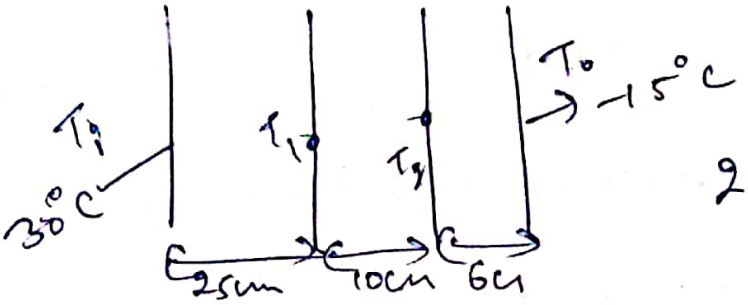
$T_s = T_f + \frac{\dot{Q}_{gen} b}{h}$

$T_s = 20 + \frac{4 \times 10^4 \times 0.1}{2 \times 50} = \frac{4000}{50 \times 2} + 20 = 60°C$

National Institute of Technology, Surathkal
Department of Chemical Engineering
Heat Transfer-CH251
Tutorial-2

State the assumptions clearly, with neat sketches solve the problems

1) The wall of a cold storage consists of three layers-an outer layer of ordinary bricks, 25 cm thick, a middle layer of cork, 10 cm thick, and am inner layer of cement, 6cm thick. The thermal conductivities of the materials are-brick:0.7, cork:0.043, and cement:0.72 W/m°C. The temperature of the outer surface of the wall is 30°C, and that of the inner is -15°C. Calculate (a) the steady state rate of heat gain per unit area of the wall, (b) the temperatures at the interfaces of the composite wall, and (c) the percentages of the total heat transfer resistance offered by the individual layers. What additional thickness of the cork should be provided to make the rate of heat transfer 30% less than the present value?



$2.94 = \frac{21.74 - T_2}{0.043}$

$2.95 = \frac{20.47 - T_0}{12}$

$q_r = \frac{AC (T_i - T_0)}{\left(\frac{L_A}{k_{AA}} + \frac{L_B}{k_B} + \frac{L_C}{k_C}\right)}$

$T_1 = 21.74$

$q_r = \frac{T_i - T_0}{\frac{1}{A}\left(\frac{L_A}{k_A} + \frac{L_B}{k_B} + \frac{L_C}{k_C}\right)}$

$\frac{2.065}{45} = \frac{1}{\left(\frac{0.7}{0.25} + 1 + 0.043\right.}$

$q_r = \frac{45}{\left(\frac{0.7}{25\times10^{-2}} + \frac{0.043}{10^{-1}} + \frac{0.72}{6\times10^{-2}}\right.}$

$= 2.95 W/m^2$

$2.95 = \frac{30 - T_1}{2.8}$

$\frac{30 - T_1}{\frac{L_A}{k_{AA}}}$

$30 - T_1 = 8.26$

2) Polyurethane foam and expanded polystyrene are two important insulations for low temperature applications. Polyuretahne can be impregnated with a flame retardant and is probably safer. It is desired to calculate the heat gain by a Horton sphere (a spherical vessel used for cryogenic storage) of 16 m diameter that contains liquid Ammonia at 4°C. The tank is insulated with a 10 cm thick layer of polyurethane foam having a thermal conductivity of 0.02 W/m°C. The outer surface temperature of the insulation is 27°C. Also, calculate the refrigeration requirement of the vessel.

$$Q = \frac{4\pi h\,(T_i - T_o)}{\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}$$

$$= -3746\,W$$

$$1\,ton = 12000\,Btu/h = 3.516\,kW$$

$$= \frac{3.746}{3.516} = 1.07\,tons$$

3) Two ends of a 5 cm diameter and 50 cm long aluminium rod, with curved surface perfectly insulated, are maintained at 30°C and 300°C, respectively. The temperature-dependent thermal conductivity of the metal is given by k=202+0.0545T, (W/m°C), where T is in °C. Calculate the temperature gradient at each end of the rod, and the temperature midway in the rod at steady state.

4) A copper wire, 5.2 mm in diameter, is insulated with a layer of PVC (PolyVinyl Chloride) of thermal conductivity kc=0.43 W/m°C. The wire carries current, and its temperature is 60°C. The film coefficient at the outer surface of the insulation is 11.35 W/m²°C. Calculate the critical insulation thickness.

$r_c = \frac{k_c}{c} =$

$r_c - r_i = ? =$

$\frac{11.35}{}$

2.6mm

$\frac{2.6 \times 10^{-3}}{0.43}$

6.046×10^{-3}

6.04mm

6.04 - 2.6

2.59mm

National Institute of Technology, Surathkal
Department of Chemical Engineering
Heat Transfer-CH251
Tutorial-3

State the assumptions clearly, with neat sketches solve the problems

variation of t with time

1. Determine the temperature response of a (1/32)- inch diameter copper wire originally at 300 F when suddenly immersed in (a)water ($h=15$ Btu/h ft^2 F) at 100 F;(b)air ($h=2$ Btu/h ft^2 F) at 100 F $k = 216$ Btu/h ft F ; $c_p = 0.091$ Btu/lb F ; $\rho = 558$ lb/ft^3

2. Determine the time required for a small aluminium casting to be heated in a furnace to 950 F by gases at 2200 F if the casting is put into the oven at 60 F. The significant length of the casting (V/A_s) is 0.5 ft and the unit-surface conductance h between the casting surface and the gases is 15 Btu/h ft^2 F. $k = 216$ Btu/h ft F, $C_p = 0.091$ Btu/lb F, $\rho = 558$ lb/ft^3

3. A concrete wall, 1ft thick and originally at 100 F, is suddenly exposed on one side to a hot gas at 1600 F. If the heat-transfer coefficient on the hot side is 5 Btu/h ft^2 F and the other side is insulated , determine (a) the time required to raise the temperature at the insulated face of the slab to 500 F, (b) the temperature distribution in the wall at that instant, and (c) the heat transferred to the wall per square foot of the surface area.

$k = 0.54 \frac{Btu}{h\,ft\,F}$, $C_p = 0.20 \frac{Btu}{lb\,F}$, $\rho = 144 \frac{lb}{ft^3}$

4. In Nagpur, the problem of preventing the freezing of oranges during cold nights is of considerable economic importance. Heat is transferred from the oranges by radiation and convection to the cold environment. To reduce the heat transfer by radiation to the cold sky and to warm the surrounding air, oil heaters, or smudge pots are used. These devices generate a smoky haze which reduces the radiant heat loss and also heats the air. To specify the heating requirements, it is necessary to estimate the temperature at the centre of a 4-inch diameter orange originally at 65 F when exposed to an environment at an effective temperature of 25 F for a period of 6 h. The overall surface conductance is estimated to be 2 Btu/h ft^2 F. Since the juice of an orange consist largely of water, the physical properties of water may be used.

5. A person is found dead at 5 pm in a room whose temperature is 20°C. The temperature of the body is measure to be 25°C when found, and the heat transfer coefficient is estimated to be h=8 W/m2 °C. Modelling the body as a 30 cm diameter, 1.7 m long cylinder, estimate the time of death of that person.

6. A short brass cylinder to diameter $D = 12$ cm and height $H = 10$ cm is initially at a uniform temperature T_i =120°C. The cylinder is now placed in atmospheric air at 25°C, where heat transfer takes place by convection, with a heat transfer coefficient of $h = 60$ W/m² °C. Calculate the temperature at (a) the center of the cylinder (b) the center of the top surface of the cylinder 15 min after the start of the cooling (c) Determine the total heat transfer from the short brass cylinder (density = 8530 kg/m³ , $C_p = 0.38$ kJ/kg °C.)

National Institute of Technology, Surathkal
Department of Chemical Engineering

Heat Transfer-CH251
Tutorial-4

State the assumptions clearly, with neat sketches solve the problems

1. For forced convection on a heated horizontal plate the local heat transfer coefficient may be expressed as $h_x(x) = Cx^{-0.5}$, where 'x' is the distance from the leading edge of the plate and 'C' is a coefficient independent of 'x'. Obtain an expression for the ratio h_{avg}/h_x where 'h_{avg}' is the average heat transfer coefficient between the leading edge and the location 'x'.

$$\bar{h}_x = h_x(x) = \frac{1}{x}\int_0^x h_x(x)\,dx$$

$$\frac{1}{x}\int_0^x Cx^{-0.5}$$

$$\bar{h}_x \quad \frac{C}{x}\,\frac{x^{0.5}}{0.5} = 2Cx^{-0.5}$$

$$\bar{h}_x = 2h_x(x)$$

$$\boxed{\frac{\bar{h}_x}{h_x} = 2}$$

2. In flow over a surface the temperature profile is known to be of the form $T(y) = A+By+Cy^2-Dy^3$, where A,B, C and D are constants. Obtain an expression for the convection coefficient, h.

$$\frac{\partial T}{\partial y} = B + 2Cy - 3Dy^2$$

$$\left.\frac{\partial T}{\partial y}\right|_{y=0} = B$$

$$\boxed{h = \frac{-k_f B}{T_s - T_\infty}}$$

3. Water flows at a velocity U_α=1 m/s over a flat plate of length L=0.6 m. Consider two cases, one for which the water temperature is approximately 300 K and the other for an approximate water temperature of 350 K. In the laminar and turbulent regions, experimental measurements show that the local convection coefficients are well described by
$h_{lam}(x) = C_{lam}x^{-0.5}$ and $h_{turb}(x) = C_{turb}x^{-0.2}$, where 'x' has units of m.
At 300 K,
$C_{lam,300K}$=394 W/m$^{1.5}$ K ; $C_{turb,300K}$ = 2330 W/m$^{1.8}$ K;
While at 350 K $C_{lam,350K}$=477 W/m$^{1.5}$ K; $C_{turb,350K}$ = 3600 W/m$^{1.8}$ K. As is evident, the constant,'C', depends on the nature of the flow as well as the water temperature because of the thermal dependence of various properties of the fluid. Determine the average convection coefficient, h_{avg}, over the entire plate for the two water temperatures.

4. Calculate the appropriate Reynolds numbers and state if the flow is laminar or turbulent for the following:

a) A 10 m (water line length) long yacht sailing at 13 km/h in water $\rho = 1000$ kg/m^3 and $\mu = 1.3 \times 10^{-3}$ kg/m s,

b) A compressor disc of diameter 0.6 m rotating at 15000 rev/min in air at 5 bar and 400°C and

$$\mu = \frac{1.46\times10^{-6}T^{3/2}}{(110+T)} \text{ kg/m s}$$

Here δ = Lseb

, T in K

c) 0.05 kg/s of carbon dioxide gas at 400 K flowing in a 20 mm diameter pipe. For the viscosity take

$$\mu = \frac{1.56\times10^{-6}T^{3/2}}{(233+T)} \text{ kg/m s}$$

use Re in terms of $\dot{m}$,

, T in K

d) The roof of a coach 6 m long, travelling at 100 km/hr in air ($\rho = 1.2$ kg/m3 and $\mu = 1.8 \times 10^{-5}$ kg/m s)

National Institute of Technology, Surathkal
Department of Chemical Engineering
Heat Transfer-CH251
Tutorial-5

State the assumptions clearly, with neat sketches solve the problems

1. Air at 20°C flows over a surface at 80°C. The local heat flow was measured at a point as 1000 W/m². Estimate the value of local convective heat transfer coefficient, temperature gradient at the surface and the temperature at a distance of 0.5 mm from the surface.

2. The temperature ratio $[(T_s - T) / (T_s - T_\infty)] = \sin(\pi y/0.015)$ in flow over a flat plate. If k = 0.03 W/mK, determine the value of convective heat transfer coefficient.

3. Water at 30°C flows over a flat plate with a free stream velocity of 0.6 m/s. Determine the local and average friction coefficient at 0.5 m from the leading edge. Also determine the local wall shear stress.

4. An appropriate expression for temperature profile in thermal layer is given by, $\theta_{(x,y)} = \frac{T_{(x,y)} - T_w}{T_\infty - T_w} = \frac{3}{2}\frac{y}{\delta_t(x)} - \frac{1}{1}\left[\frac{y}{\delta_t(x)}\right]^3$ and thickness of boundary layer is given by, $\delta_t(x) = 4.53 \frac{x}{Re_x^{1/2}\, Pr^{1/3}}$. Develop an expression for local heat transfer co-efficient, h(x).

5. The exact expression for the local Nusselt number for laminar flow of air at 300K along a flat plate maintained at 400K is given by: $Nu_x = 0.332\, Pr^{1/3}\, Re_x^{1/2}$, $u_\infty = 1.5 m/s$
   a. Develop a relation for average heat transfer co-efficient for the distance between points, x=0 and x=L.
   b. Calculate average heat transfer co-efficient for x=0 to x = 2 m.
   c. Calculate heat transfer rate from air to plate of width 0.5 m and length 2m.

Department of Chemical Engineering, NITK
CH-251: Heat Transfer
B.Tech., Quiz - I; 6th February 2017

Time: 50 mins **Total Marks: 20**

Answer all the Questions
(Assume suitable data wherever necessary and clearly state them)

1. (a) A large concrete slab 1 m thick has one dimensional temperature distribution:
$T=4-10x+20x^2+10x^3$
Where, 'T' is temperature and 'x' is distance from one face towards other face of wall. If the slab material has thermal diffusivity of 2×10^{-3} m^2/h, what is the rate of change of temperature at the other face of the wall? **(2)**
(b) Why are metals good conductors of heat? **(1)**
(c) A composite wall of a furnace has 2 layers of equal thickness having thermal conductivities in the ratio of 3:2. What is the ratio of the temperature drop across the two layers? **(2)**

2. A furnace wall consists of 200 mm of refractory fireclay brick, 100 mm of kaolin brick, and 6 mm of steel plate. The fire side of the refractory is at 1150 °C, and the outer side of the steel is at 30 °C. An accurate heat balance over the furnace shows the heat loss from the wall to be 300 W/m². It is known that there may be thin layers of air between the layers of brick and steel. To how many millimeters of kaolin are these air layers equivalents? The thermal conductivity values of fireclay brick, kaolin brick and steel plate are 1.7, 0.11, and 45 W/(m · °C), respectively. **(07)**

3. An ice-skating rink is located in an indoor shopping mall with an environmental air temperature of 22°C and radiation surrounding walls of about 25°C. The convection heat transfer coefficient between the ice and air is about 10 W/ (m² · °C), because of air movement and the skaters' motion. The emissivity of the ice is about 0.95. Calculate the cooling required to maintain the ice at 0°C for an ice rink having dimensions of 12 by 40 m. Obtain a value for the heat of fusion of ice and estimate how long it would take to melt 3 mm of ice from the surface of the rink if no cooling is supplied and the surface is considered insulated on the back side. **(08)**

2: $\frac{q}{A} = \frac{\Delta T}{\left(\frac{S_1}{k_1} + \frac{S_2}{k_2} + \cdots +\right)}$

x = equivalent kaolin brick thickness for air layer

$300 = \frac{1120°C}{\left(\frac{0.2}{1.7} + \frac{x+0.1}{0.11} + \frac{6\times10^{-3}}{45}\right)}$

$\frac{x+0.1}{0.11} = \frac{1120}{300} - \frac{0.2}{1.7} - \frac{0.006}{45}$

$x = 0.283$ m

Department of Chemical Engineering, NITK

CH-251: Heat Transfer

B.Tech., Mid-Semester; February 08, 2018

Time: 1.5 hours **Total Marks: 50**

Answer all the Questions

(Make valid assumptions wherever necessary and clearly state them)

(1) A closed container filled with hot cofee is in a room whose air and walls are at a fixed temperature. Identify all heat transfer processes that contribute to cooling of the coffee. Comment on features that would contribute to a superior container design **(10 marks)**

(2) An insulated steam pipe passes through a room in which the air and walls are at 25°C. The outside diameter of the pipe is 70 mm, and its surface temperature and emissivity are 200°C and 0.8, respectively. What are the surface emissive power and irradiation? If the coefficient associated with free convection heat transfer from the surface to the air is 15 W/m^2 K, ~~what is the rate of heat loss from the surface to the air is 15 W/m² K.~~ What is the rate of heat loss from the surface per unit length of pipe? **(10 marks)**

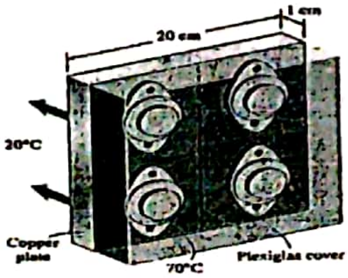
(3) Consider a homogenous medium within which there is no bulk motion (advection) and the temperature distribution is expressed in cylindrical coordinates. Following the methodology of applying the conservation of energy, for the case of uniform heat generation within the medium, derive a general three-dimensional unsteady state differential heat diffusion equation. **(12marks)**

(4) A long copper bar of rectangular cross-section, whose width 'W' is much greater than its thickness 'L', is maintained in contact with a heat sink at its lower surface, and the temperature throughout the bar is approximately equal to that of the sink, To. Suddenly, an electric current is passed through the bar and an air stream of temperature T_∞ is passed over the top surface, while the bottom surface continues to be maintained at To. Obtain the differential equation and the boundary and initial conditions that could be solved to determine the temperature as a function of position and time in the bar.

(06marks)

(5) Four identical power transisitors with aluminium casing are attached on one side of a 1 cm thick 20 cm X 20 cm square copper plate (k=386 W/m °C) by screws that exert an average pressure of 6 MPa. The base area of each transistor is 8 cm^2, and each transistor is placed at the center of a 10 cm X10 cm quarter section of the plate. The interface roughness is estimated to be about 1.5 μm. All transistors are covered by a thick plexiglass layer, which is a poor conductor of heat, and thus all the heat generated at the junction of the transistor must be dissipated to the ambient at 20°C through the back surface of the copper plate. The combined convection/radiation heat transfer coefficient at the back surface can be taken to be 25 W/m^2°C.If the case temperature of the transistor is NOT to exceed 70°C, determine the maximum power each transistor can dissipate safely, and the temperature jump at the case-plate interface. The contact conductance at the copper-aluminium interface conditions is 42000 W/m^2°C.

(12 marks)



49

Department of Chemical Engineering, NITK
CH-251: Heat Transfer
B.Tech., Mid-Semester; February 13, 2017

Time: 1.5 hours **Total Marks: 50**

Answer all the Questions
(Make valid assumptions wherever necessary and clearly state them)

(1) Consider a homogenous medium within which there is no bulk motion (advection) and the temperature distribution is expressed in spherical coordinates. Following the methodology of applying the conservation of energy, for the case of uniform heat generation within the medium, derive a general three-dimensional unsteady state differential heat diffusion equation. **(15marks)**

(2) (i) A plane wall is fitted with an aluminium pin fin of 1 cm diameter and 30 cm length. The fin base temperature is 300°C and the pin fin is in contact with air at 30°C. Assuming that the fin is infinitely long and free convection happening at the surface of the fin, calculate the temperature at 15 cm from the base and the rate of heat transfer from the fin. **(5 marks)**

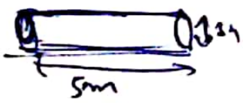
(ii) Two perfectly black surfaces are separated from each other and are enclosed such that all the radiant energy leaving the surface at 1000°C reaches the other surface maintained at 200°C. Calculate the net rate of radiation heat transfer per unit area of the first surface. **(3 marks)**

(iii) Consider one-dimensional steady state heat conduction along x-axis ($0 \le x \le L$), through a plane wall with the boundary surface (x=0 and x=L) maintained at temperatures of 0°C and 100°C. Heat is generated uniformly throughout the wall. Choose the correct statement.
(a) The direction of heat transfer will be from the surface at 100°C to the surface at 0°C.
(b) The maximum temperature inside the wall must be greater than 10°C.
(c) The temperature distribution is linear with in the wall.
(d) The temperature distribution is symmetric about the mid-plane of the wall.

(2marks)

(3) A short brass cylinder to diameter $D = 12$ cm and height $H = 10$ cm is initially at a uniform temperature T_i =120°C. The cylinder is now placed in atmospheric air at 25°C, where heat transfer takes place by convection, with a heat transfer coefficient of $h = 60$ W/m^2°C. Calculate the temperature at (a) the center of the cylinder (b) the center of the top surface of the cylinder 15 min after the start of the cooling (c) Determine the total heat transfer from the short brass cylinder. **(15 marks)**

(4) A 3mm diameter and 5 m long electric wire is tightly wrapped with a 2mm thick plastic cover whose thermal conductivity is 0.15W/m°C. Electrical measurements indicate that a current of 10 amperes passes through the wire and there is a voltage drop of 8V along the wire. If the insulated wire is exposed to a medium at 30°C with a heat transfer coefficient of 12W/m^2°C, determine the temperature at the interface of the wire and the plastic cover in steady operation. Also, determine whether doubling the thickness of the plastic cover will increase or decrease this interface temperature. **(10 marks)**



$H = I^2R$

Department of Chemical Engineering, NITK
CH-251: Heat Transfer
B.Tech., End-Semester; April 21st, 2017

Time: 3 Hours **Total Marks: 100**

Answer all the Questions

(Make valid assumptions wherever necessary and clearly state them)
(Allowed to refer Steam Tables, and Heat and Mass Transfer data book)

1. An ice-ball of initial diameter 0.06 m is suspended in a room at 30°C. The ice melts by absorbing heat from the ambient, the surface heat transfer coefficient being 11.4 $W/m^2{}^\circ C$. The air in the room is essentially dry. If the shape of the ball remains unchanged, calculate the time required for reduction in its volume by 40%. The density of ice is 929 kg/m^3 and its latent heat of fusion is 3.35×10^5 J/kg. **(15 marks)**

2. Consider 1-D, steady state heat conduction in a hollow cylinder with constant thermal conductivity in the region 'a'< r < 'b'. Heat is generated in the cylinder at a rate of 'g_o' W/m^3, while it is dissipated by convection into fluids flowing inside and outside the cylindrical tube. Heat transfer coefficients for the inside and outside fluids are 'h_a' and 'h_b' respectively and temperatures of the inside and outside fluids are 'T_a' and 'T_b' respectively. Write the mathematical formulation of this heat conduction problem. **(5 marks)**

3. A nuclear fuel rod is in the form of a long solid rod (k=0.85 W/m K) of diameter 14mm. It generates heat at the uniform rate of 0.45×10^8 W/m^3, because of nuclear fission. The heat is transferred to pressurized cooling water at 300°C and the surface heat transfer coefficient is 4500 W/m^2K. Calculate the highest temperature in the fuel rod in the steady state. **(5 marks)**

4. Air flow through a long rectangular (30cm height x 60 cm width) air conditioning duct maintain the outer duct surface temperature at 15°C. If the duct is un-insulated and exposed to air at 25°C, calculate the total heat gained by the duct per metre of length, assuming it to be horizontal. **(15 marks)**

5. A cylindrical biomass particle is initially at a temperature 'T_o' and is suddenly dropped into a hot combustor surroundings of temperature 'T_α' which is higher than 'T_o'. Draw a qualitative sketch of the temperature distribution inside the heated biomass particle for the below three cases, at various times after the exposure. Case (i) Bi $\rightarrow\infty$, (ii) $0 < Bi < \infty$, and (iii) $Bi \rightarrow 0$. Where 'Bi'- Biot number. **(5 marks)**

6. A 2-m X 3-m flat plate is suspended in a room, and is subjected to air flow parallel to its surfaces along its 3-m-long side. The free stream temperature and velocity of air are 20°C and 7 m/s. The total drag force acting on the plate is measured to be 0.86N. Determine the average convection heat transfer coefficient for the plate **(7 marks)**

7. Water is boiled at a rate of 30 kg/h in a copper pan, 30 cm in diameter, at atmospheric pressure. Estimate the temperature of the bottom surface of the pan assuming nucleate boiling conditions **(15 marks)**

8. (i) A counter flow heat exchanger is used to heat water from 20°C to 80°C by using hot exhaust gas entering at 140°C and leaving at 80°C. Calculate the log mean temperature difference for the heat exchanger. **(3 marks)**

(ii) In a gas turbine power plant heat is transferred in a plate-fin heat exchanger from the hot gases leaving the turbine to the air leaving the compressor. The air flow rate is 5000 kg/h and the flow rate of hot gases is 5075 kg/h. Given the inlet temperature of hot and cold fluids as 450°C and 170°C, respectively; overall heat transfer coefficient is 52 W/m²°C; surface area is 50 m²; the specific heat of both cold and hot fluids is 1050 J/kg °C. The flow arrangement of the heat exchanger is single pass cross flow with both fluids unmixed. By Effectiveness-NTU method, find the exit temperatures of hot and cold fluid and the heat transfer rate. **(15 marks)**

9. (i) Define the following terms
   a. Black and gray surfaces **(3 marks)**
   b. Monochromatic hemispherical irradiation **(2 marks)**

   (ii) Name the important parameters that quantify the directional nature of thermal radiation and define them. **(5 marks)**

   (iii) A small blackbody has a total hemispherical emissive power of 4 kW/m². Determine its surface temperature and the wavelength of emission maximum. In which range of the spectrum does this wavelength fall? **(5 marks)**

$\dot{m} \times \ell$ $\frac{J}{hr}$ $\frac{Q}{A} = 8.058\,\Delta T$ $\frac{W}{m\cdot K} \cdot \frac{k}{m}$ $\frac{kg}{8.h?}$

$= \frac{kg \cdot kJ}{h \cdot kg}$ (W) $=$ $\frac{kg \cdot \text{whr} \cdot W}{hr \times m^2 \cdot kg \cdot m^2}$ $\frac{W}{m^2}$